TABLE I

BUFFER TEMPERATURES AT THE CENTER AND AT THE WALL OF THE CAPILLARY

Parameters used: $L = 1$ m; $R_2 = 1.725 \times 10^{-4}$ m; $R_c = 1.875 \times 10^{-4}$ m; $T_s = 298$ K; $h = 10\,000$ W/m^{2}K; $k_1 = 0.605$ W/mK; $k_2 = 1.5$ W/mK; $k_c = 0.155$ W/mK; $\alpha = 7.75$.

Power (W)	*Eqn. 8*			*Parabolic*		
	Center (K)	*Wall (K)*	*ΔT (K)*	*Center (K)*	*Wall (K)*	*ΔT (K)*
Internal diameter = 50 μm						
2	299.214	298.951	0.263	299.214	298.951	0.263
3	299.722	299.326	0.396	299.721	299.326	0.395
5	300.738	300.077	0.661	300.735	300.077	0.658
Internal diameter = 100 μm						
2	299.067	298.804	0.263	299.067	298.804	0.263
3	299.501	299.106	0.395	299.500	299.106	0.394
5	300.370	299.709	0.661	300.367	299.709	0.658

found from the two methods of calculation. Shown in Table I are results for several capillary internal radii and power inputs. The results in Table I have several important implications: (a) typical CZE systems exhibit small temperature drops between the center and the wall —under the usual operating conditions, temperature effects are minimal[2]; (b) within the limits of the power input shown in the table, the temperature difference between the center and the inner wall of the capillary is independent of the inner radius. However, the actual temperatures are a function of the internal radius, showing a decrease with an increase in the diameter; (c) the temperatures calculated using eqn. 8 are identical, for all practical purposes, to those calculated from eqn. 12 over the whole cross section of the capillary. Fig. 1 shows the temperature profile within the capillary. The line depicting the temperature behavior is actually the superposition of two lines, one calculated using eqn. 8 and the other calculated using the parabolic profile, eqn. 12.

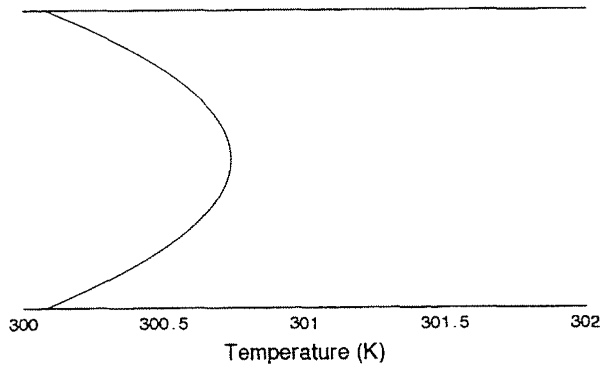

Fig. 1. Temperature profile as calculated from eqn. 8. Parabolic equation yields identical profile. Parameters used in the calculations are identical to those in Table I. Input power, 5 W; radius of capillary, 25 μm.

TABLE II

BUFFER TEMPERATURE AT THE CENTER AND AT THE WALL AT HIGH INPUT POWERS

Parameters used: $L = 1$ m; $R_2 = 1.725 \times 10^{-4}$ m; $R_c = 1.875 \times 10^{-4}$ m; $T_a = 298$ K; $h = 10000$ W/m^{2}K; $k_1 = 0.605$ W/mK; $k_2 = 1.5$ W/mK; $k_c = 0.155$ W/mK; $\alpha = 7.75$; internal diameter $= 50$ μm.

Power (W)	*Eqn. 8*			*Parabolic*		
	Center (K)	*Wall (K)*	*ΔT (K)*	*Center (K)*	*Wall (K)*	*ΔT (K)*
10	303.280	301.954	1.326	303.270	301.954	1.315
15	305.826	303.832	1.995	305.805	303.832	1.973
25	310.930	307.586	3.344	310.874	307.586	3.288

Table I describes the results for a capillary whose overall outer diameter is 375 μm. The conclusions drawn from the table are valid even if the capillary radius is changed, provided that the power input is the same. Eqn. 8 and the parabolic profile will yield similar results as long as the power input is relatively small. When the power is increased, the discrepancy between the two temperature profiles increases. Table II shows the results of the calculation for power inputs of 10, 15 and 25 W. If the CZE system is thermostated, such power inputs can be tolerated, as evidenced from the relatively low predicted temperatures. We see from Table II that as the power increases, eqn. 8 predicts a greater temperature difference between the center and the inner wall of the capillary. Both, eqns. 8 and 12 give a similar wall temperature. However, eqn. 8 calculates a higher center temperature than the parabolic equation. Fig. 2 shows the temperature profile as determined by both approaches. From Fig. 2 we can see that the greatest difference between eqn. 8 and the parabolic equation occurs in the center of the capillary. The difference between the two profiles is small even at very high power input values, which are not used in the conventional practice of CZE (*e.g.*, 0.06 degree difference at a power input of 25 W). At such high input powers, the temperature difference between center and wall is rather high (above 3 degrees) so that the contribution to the plate height is prohibitively high[2].

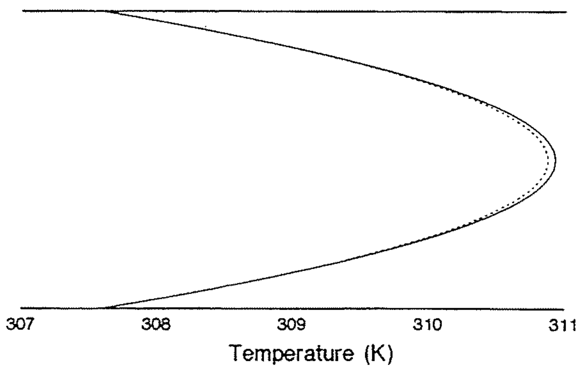

Fig. 2. Temperature profiles as calculated from eqn. 8 (——) and from the parabolic equation (----). Parameters used in the calculations are identical to those in Table II. Input power, 25 W; radius of capillary, 25 μm.

With relatively wide tubes (several mm in diameter), the resulting current is quite high at voltages which yield reasonable analysis times. In such cases, the power dissipated in the tube is very high, and eqn. 8 will be more accurate than eqn. 12 in predicting the temperature profile. However, the use of very wide tubes for CZE is not recommended since the temperature difference between center-to-wall will be much too large to obtain efficient separations.

CONCLUSIONS

Under the normal operating conditions, the nearly identical behaviors of eqns. 8 and 12, justify the use of parabolic temperature profiles in determining the effect of temperature on the efficiencies of CZE separations[2].

SYMBOLS

A Integration constant
G heat generation rate (W/m^3)
G_0 heat generation in the absence of temperature dependence of the buffer (W/m^3)
h heat transfer coefficient (W/m^2K)
J_0 Bessel function of zero order and first kind
J_1 Bessel function of first order and first kind
k_1 thermal conductivity of the buffer (W/mK)
k_2 thermal conductivity of the capillary wall (W/mK)
k_c thermal conductivity of the polyimide coating (W/mK)
L capillary length (m)
R_1 inner radius of the capillary (m)
R_2 outer radius of the quartz wall (m)
R_c outer radius of the capillary; glass and polyimide (m)
S reduced coefficient of heat generation (see eqn. 4)
T_1 temperature at the inside wall of the capillary (K)
T_s temperature of the capillary surrounding (K)
U overall heat transfer coefficient (W/m^2K)
y_1 dimensionless radial position r/R_1
α coefficient of electrical conductivity of the buffer (dimensionless)
β $(\alpha S)^{1/2}$
γ reduced heat transfer coefficient (see eqn. 6)
θ reduced temperature (see eqn. 4)

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TAB 5

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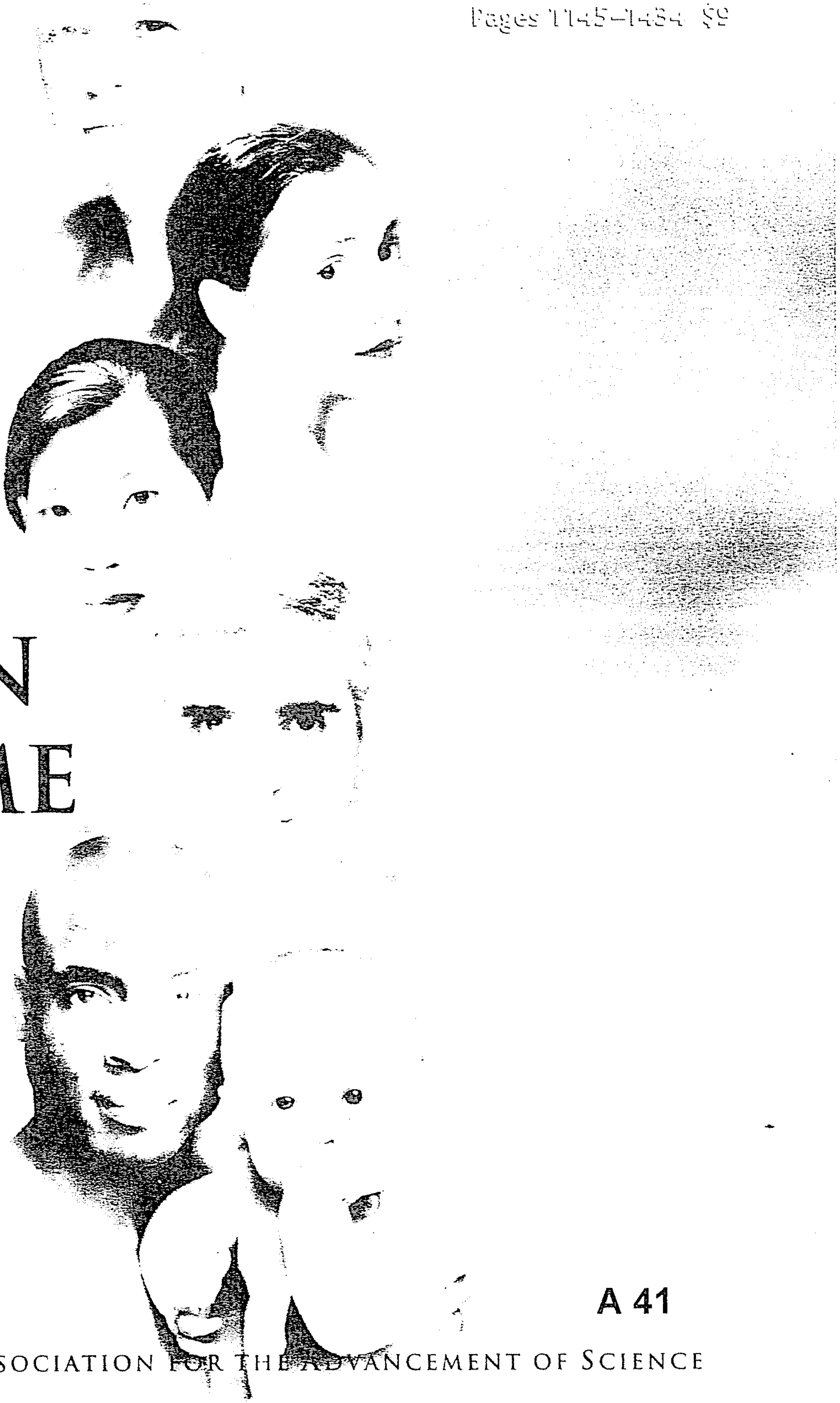

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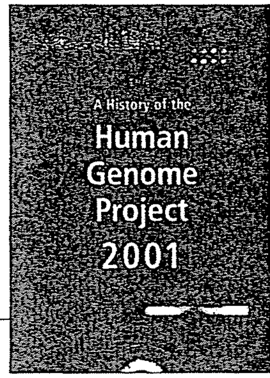

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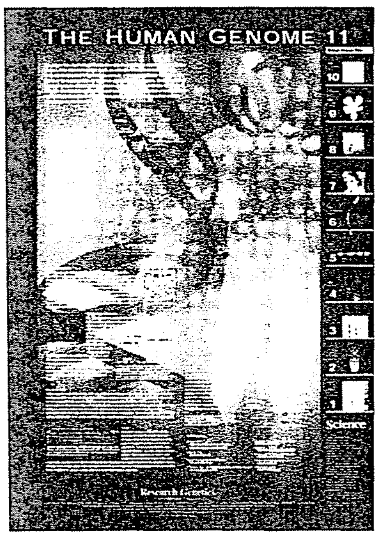

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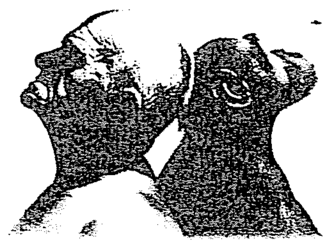

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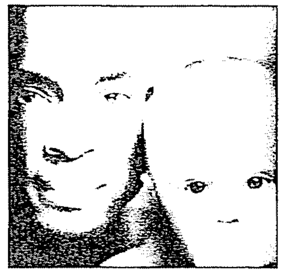

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THE HUMAN GENOME

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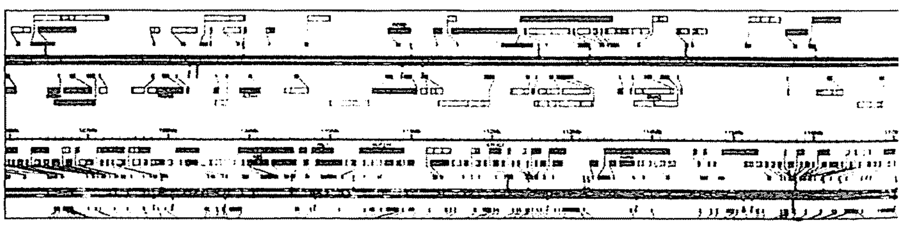
Annotation of the Celera Human Genome Assembly (Fig. 1 of Venter *et al.*, included as a separate wall chart)



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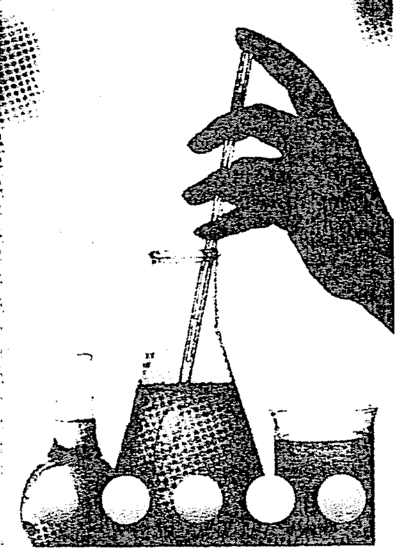

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